Ohio Geology

A Quarterly Publication of the Division of Geological Survey | Winter 1997

THE GEOLOGY OF OHIO—THE CAMBRIAN

by Michael C. Hansen

The beginning of the Cambrian Period about 570 million years ago seems like an incredibly ancient event, which it was, but it was relatively late in the history of the 4.6-billion-year-old Earth. Indeed, nearly 90 percent of Earth's history had elapsed before the beginning of the Cambrian. Were it not for a dramatic occurrence—the sudden, widespread appearance of multicellular marine animals with hard parts capable of fossilization—the 65-million-year-long Cambrian would not be regarded as the beginning of a new, and perhaps the most significant, era in the history of the Earth. Economically, Cambrian rocks mark the first widespread accumulation of hydrocarbons, organic substances derived from once-flourishing life that are now integral to most human existence.

The Cambrian System was named for a succession of rocks in the Harlech Dome area of Wales by Adam Sedgwick, who began his studies of these rocks in 1831, accompanied by a young assistant, Charles Darwin. The name "Cambrian" is derived from the Roman name for Wales: Cambria. The apparent sudden appearance of fossils in rocks overlying unfossiliferous Precambrian rocks was a dramatic discovery to early geologists in their attempts to divide geologic time because the base of the Cambrian System marked the beginning of the Paleozoic Era, the era of ancient life.

Like Precambrian rocks in Ohio, Cambrian rocks underlie the state but are nowhere exposed at the surface. These rocks must therefore be studied using information obtained from deep oil and gas wells and indirect geophysical techniques such as seismic reflection, gravity, and magnetic intensity. The information on Cambrian rocks greatly exceeds that of the Precambrian because Cambrian rocks in Ohio have been pierced many times by the oil explorationist's drill. However, our knowledge of the Cambrian System is still meager in comparison to younger Paleozoic rocks that are known from surface exposures.

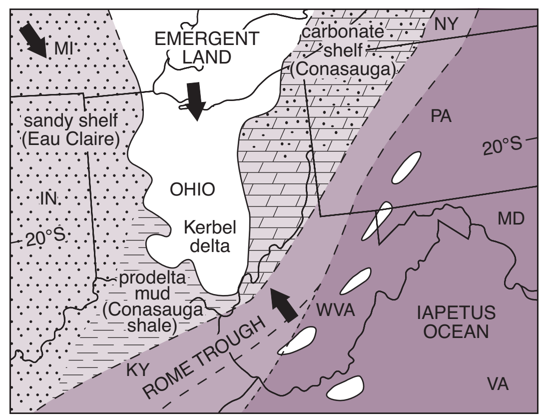
GEOLOGIC HISTORY

Significant geologic events late in Precambrian time set the stage for sediment deposition during the Paleozoic (see *Ohio Geology*, Winter 1996). Continental collision about a billion years ago formed the Grenville Mountains in a north-south chain across Ohio and adjacent areas, older rocks were thrust westward in western Ohio along a zone known as the Grenville Front, and extensive downdropped basins, known as rift zones, formed west of the Grenville Front.

At the close of this tectonic activity, the land surface in Ohio probably had considerable relief, including extensive, and perhaps lofty, mountains. During the next 500 million years, until the beginning of the Cambrian Period about 570 million years ago, significant erosion must have been the prevalent geologic force. The western Ohio rift basins accumulated up to 20,000 feet of sediment, which implies extensive reduction of the adjacent upland surface. There is little evidence of the amount of rain that fell on these uplands, but the lack of terrestrial vegetation would have contributed to the rate of erosion. We do know that the surface of the land in Ohio was reduced to a gentle, rolling landscape by Cambrian time. Data from oil and gas wells suggests that local relief on the Precambrian surface was not much more than about 300 feet at the time of deposition of Cambrian sediments.

Toward the end of the Precambrian and continuing into the Cambrian, the Laurentian continental plate (North America) began to separate from an eastern continental mass, probably Baltica (northern Europe), and the Iapetus Ocean formed. Ohio was on the stable, passive margin of the Laurentian continent, the nucleus of which was formed by the ancient Canadian Shield. The opening of the Iapetus Ocean resulted in tensional (pull-apart) stresses that formed fault-bounded crustal blocks, which subsided to form troughlike features known as aulacogens. One of these, the Rome trough, formed south and east of Ohio in Kentucky, West Virginia, and Pennsylvania and was the site of accumulation of a thick sequence of Cambrian sediments.

The basal Cambrian rock unit in most of Ohio is the Mt. Simon Sandstone, a quartzose sandstone that is widespread across a multistate area. The unit consists of friable, fine- to coarse-grained sandstone that ranges from 0 to nearly 400 feet in thickness. It tends to be thicker in western Ohio and thinner toward the east. There are considerable variations in thickness of the unit that appear to correlate with the relief of the Precambrian surface upon which it was deposited. The Mt. Simon is unfossiliferous and its precise age is therefore un-



Generalized paleogeography of Ohio and adjacent areas during late Middle Cambrian time. At this time, sandy deposits of the Kerbel delta dominated the central part of the state. South of and underlying the delta are prodelta muds (Conasauga Formation). To the west are sandy shelf deposits of the Eau Claire Formation, and to the east are muddy carbonate shelf deposits of the Conasauga Formation. The subsiding Rome trough south and east of Ohio accumulated a great thickness of Cambrian sediments. East of the Rome trough was the continental edge and the Iapetus Ocean, which may have been bordered by islands or even a low, emergent barrier that was a lesser sediment source. Most clastic sediment came from the emergent Canadian Shield to the north (arrows). Figure based on maps by Janssens (1973), Beardsley and Cable (1983), and Lochman-Balk (1970).

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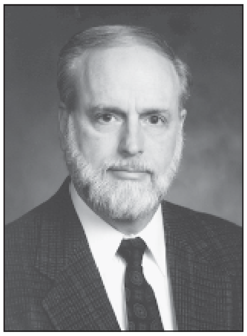

Thomas M. Berg, Division Chief and State Geologist

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From The State Geologist...

Thomas M. Berg

SPEEDING HOME ALONG THE INFORMATION SUPERHIGHWAY

I am continually dazzled by our breakneck acceleration in the use of computer technology in the geosciences. In the Spring 1996 issue of *Ohio Geology*, I commented on the remarkable world of computers and how they are being used at the Ohio Geological Survey to increase efficiency and effectiveness. Indeed, in this time of government downsizing, rightsizing, and privatizing, we are able to deal with the pressures of "doing more with less" by relying more and more on computers to manage the huge amounts of geological information that are part of our life at the Survey. We are able to crunch numbers, process geological data, and produce geologic reports with awesome alacrity. Ohio citizens can expect to obtain geologic information and interpretations with great dispatch.

The future release of geologic information will escalate to solely electronic means. Information that traditionally has been disseminated as printed publications will increasingly be distributed by electronic techniques. The Division of Geological Survey is particularly proud of its new home page, which may be accessed on the Internet at *http://www.dnr.state.oh.us/odnr/geo_survey/*. I am personally proud of, and grateful to, the Ohio Survey staff who worked together to make our home page the truly outstanding Web site that it is. They call themselves the Web Force and serve as one of our quality-improvement teams. The team includes Merrianne Hackathorn, Mike Hansen, Glenn Larsen, Jim McDonald, Rick Pavey, Lisa Van Doren, and Sherry Weisgarber. Former Survey geologist Allan Axon (now at the North Carolina Survey) also served on the team.

When users browse our home page, they will see at once that we are proud of our long history of public service (160 years). The various "pages" of information are graced with archival photographs of many of our predecessors, including some of the early State Geologists. The "front" page of the Web site is embellished with a photograph of the fossil head of *Dunkleosteus*, the huge, frightful fish that roamed the Late Devonian sea in Ohio. Our staff each have a "page" to themselves, and some have selected photographs or illustrations of themselves that bring their personality to the fore. The Survey's *List of publications* is loaded on the Web site, and there are full instructions on how to acquire publications. There are educational materials such as *GeoFacts* and *Hands On Earth Science* which can be downloaded and printed out for class use or reference. There are even color photographs of our two research vessels which ply the waters of Lake Erie.

The Ohio Survey home page will be expanded and updated. More information will be available in the future. Users will be able to access massive databases and download information for geologic research. We invite *Ohio Geology* readers to speed over the information superhighway and visit our "home." The welcome mat is out.

Revised publications list for educators

The *Ohio Division of Geological Survey list of educational resources* is in its fourth revision. The list includes educational resources of the Survey and of the Ohio Department of Natural Resources, plus other sources of information from federal agencies and private organizations, for kindergarten through college teachers, such as activity books, science books, catalogs, videos, workshops, science programs, rock and mineral clubs, and newsletters. Prices of materials are included; however, many of the resources are free. To obtain a free copy of the list contact the Geologic Records Center at 614-265-6576.

Editor's note: Fall 1996 issue of Ohio Geology

Many readers of *Ohio Geology* may wonder why they have not received their Fall 1996 issue. It has not been lost in the mail; indeed, it has not been mailed. The reason for this delay is that the Fall issue describes the Division's new, long-awaited publication, Bulletin 70, *Fossils of Ohio*, and contains ordering information. Bulletin 70 and the Fall issue of *Ohio Geology* were delivered from different printers on the same day in December; however, the print quality of Bulletin 70 was not acceptable and the book is being reprinted. The Fall 1996 issue of *Ohio Geology* will be mailed as soon as copies of Bulletin 70 are available. We apologize for any inconvenience or confusion this has caused our readers.

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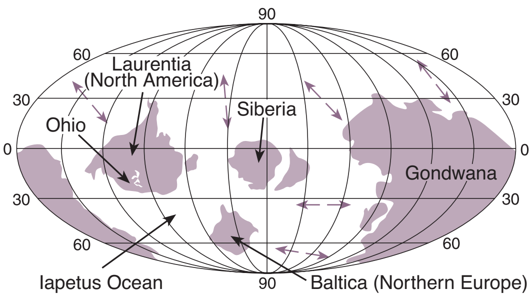


Continental configuration in the Late Cambrian. Ohio was near the continental edge of Laurentia in south equatorial latitudes. Modified from Riley and others (1993).

certain. Traditionally, the Mt. Simon has been considered to be Late Cambrian in age. However, discovery (see *Ohio Geology*, Spring 1992) of trilobite fossils in core samples of the upper part of the younger Eau Claire Formation and the lower part of the Knox Dolomite suggests that the Mt. Simon may be even older. The trilobites indicate that these units overlying the Mt. Simon are late Middle Cambrian to early Late Cambrian in age, and thus that the Mt. Simon may be Early or Middle Cambrian in age.

The depositional environment of the Mt. Simon is not well understood. High-purity quartz sandstones such as the Mt. Simon are commonly the result of multiple erosion cycles during which less resistant rock fragments are removed, leaving an end product of quartz grains. It is thought that the lower part of the Mt. Simon may represent an accumulation of quartz grains derived from a long period of weathering of underlying Precambrian rocks. Transgression of the Cambrian seas across the shallow shelf on the edge of the craton reworked these sand deposits.

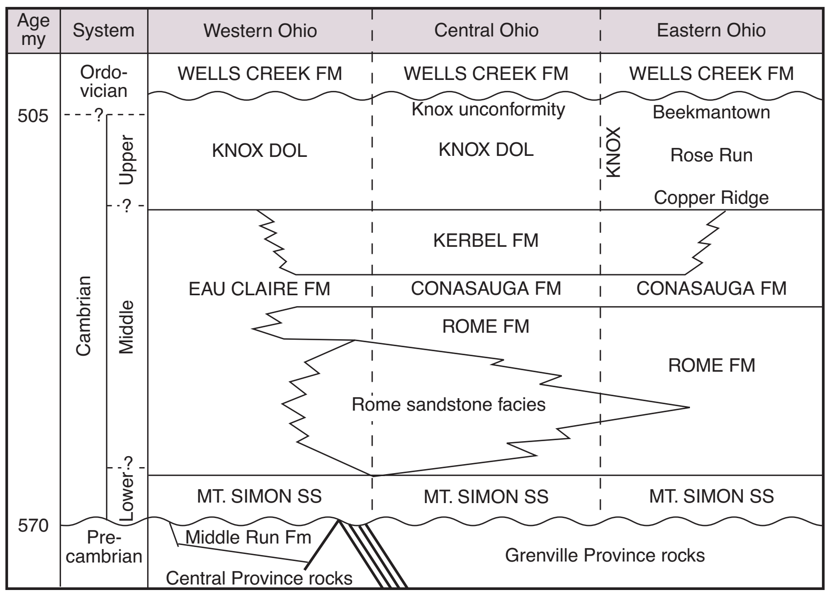
As the Cambrian sea continued to flood the long-emergent craton during the opening of the Iapetus Ocean, the waters deepened across Ohio and carbonate deposition began in eastern Ohio as the Rome Formation, which is primarily dolomite, accumulated. The Rome is more than 700 feet thick in far eastern Ohio, becomes sandy in central Ohio, and thins to the west. Overlying the Rome Formation in the eastern half of the state is the Conasauga Formation, which consists of shale, siltstone, fine-grained sandstone, and limestone in the south and dark-gray to brown dolomite and interbedded fine- to coarse-grained sandstone in the north. The Conasauga ranges in thickness from 40 feet to more than 400 feet.

The Rome and Conasauga Formations grade westward into the Eau Claire Formation, which is composed of sandstone, siltstone, shale, and dolomite. (Such a gradational relationship is called a facies.) The Eau Claire ranges in thickness from about 200 feet to more than 500 feet.

The Rome/Conasauga and Eau Claire facies are interpreted to represent shallow-shelf and prodelta deposits derived from a northwest source area. They are offshore deposits related in part to the overlying unit, the Kerbel Formation, an upward coarsening sandstone that is interpreted to be a wedge of deltaic sediments. The Kerbel is a north-south-oriented lobate deposit in the central part of the state and reaches a thickness of about 170 feet. It is absent in southernmost, western, and eastern Ohio.

During the Late Cambrian the Kerbel delta foundered and carbonate sediments began to accumulate as shelf deposits in the shallow sea that covered Ohio. These carbonate sediments, which now form the Knox Dolomite, are more than 1,360 feet thick in the southern part of the state and thin to the north beneath a major regional unconformity. The Knox carbonates accumulated in shallow water, in many cases in peritidal (between high and low tides) environments in arid, equatorial latitudes. Knox deposition continued throughout the remainder of the Cambrian and into the Ordovician Period. The Cambrian-Ordovician boundary therefore is uncertain, lying within the upper part of the Knox but not marked by a significant unconformity.

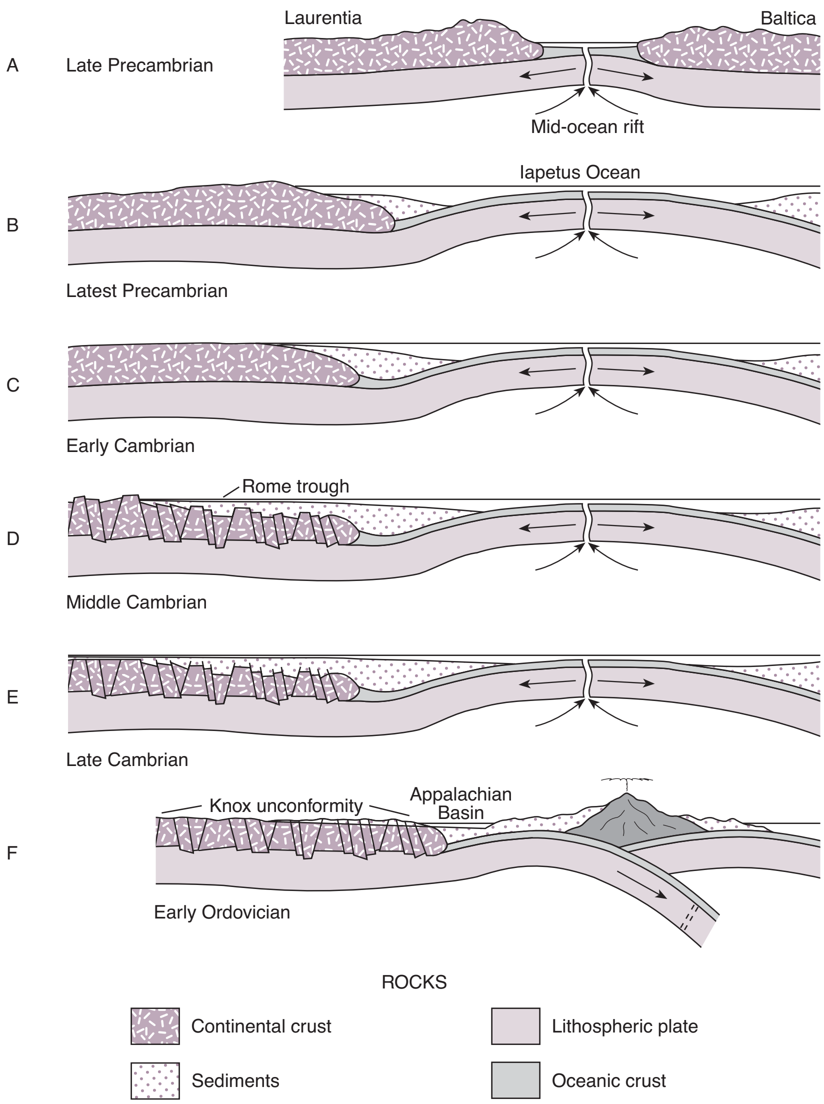
Early in the Ordovician Period, Knox carbonate deposition ceased when sea level dropped or the land was elevated. This relative lowering of sea level was a result of closing of the Iapetus Ocean as the Afro-Eurasian plate moved toward the North American plate, eventually resulting in a collisional episode known as the Taconic Orogeny. These events uplifted the continental shelf in what is now Ohio and adjacent areas, exposing the former sea floor to widespread subaerial erosion that created



Cambrian rocks in Ohio. Relationships of Cambrian rocks and underlying and overlying systems are depicted from west to east across the state. The precise positions of the Cambrian-Ordovician boundary and the boundaries between Lower, Middle, and Upper Cambrian rocks are uncertain. Copper Ridge, Rose Run, and Beekmantown are informal subdivisions of the Knox Dolomite. None of these rocks are exposed at the surface in Ohio. my = million years. Modified from Janssens (1973).

an extensive unconformity marked by relief of at least 150 feet and well-developed hills and valleys and karst features. Significant amounts of Knox sediments were removed during this process. The laterally extensive Knox unconformity is well known to geologists and drillers and was once interpreted to be the boundary between the Cambrian and Ordovician Systems. The package of rocks from the Precambrian unconformity to the Knox unconformity has been referred to as the Sauk Sequence.

The Knox Dolomite illustrates the confusing nomenclature that is associated with many rock units. This unit was formerly subdivided, in ascending stratigraphic order, into the Copper Ridge (Trempealeau), Rose Run, and Beekmantown. None of these names, which are derived from other geographic areas, have formal stratigraphic status in



Cross sections of the Iapetus Ocean and the North American continent (Laurentia) from Late Precambrian through Early Ordovician. The Iapetus Ocean formed in Late Precambrian time but began to close in the Ordovician as the North American and Afro-Eurasian plates collided in the Taconic Orogeny. The Knox unconformity formed as the seas withdrew, exposing Ohio and adjacent areas to subaerial erosion. Modified from Riley and others (1993).

Ohio but they are still widely used in an informal sense. The Rose Run, a sandy zone near the top of the Knox, is a widely discussed unit because it is a prime drilling target for oil and gas in eastern Ohio.

ECONOMIC AND ENVIRONMENTAL IMPORTANCE OF CAMBRIAN ROCKS

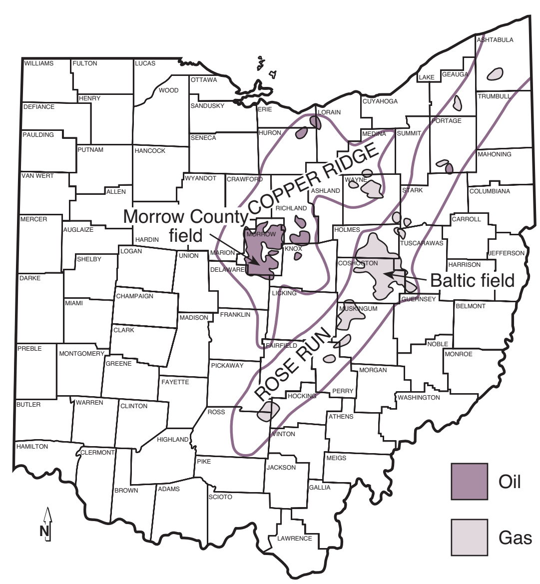
Cambrian rocks in Ohio have been the last of the Paleozoic systems to be explored for economic benefits because of their great depth below the surface. The first Cambrian hydrocarbon production was in 1919 from the Knox Dolomite in Marion County. This well produced 45 barrels of oil per day. Thus far, only the Knox and Kerbel have had economic production. The Mt. Simon Sandstone and the Eau Claire, Rome, and Conasauga Formations have had noneconomic shows of hydrocarbons.

Wildcat drilling, beginning in 1959, in Morrow County quickly made Cambrian rocks one of the most important geologic systems in the state for oil and gas production. The discovery well, the #1 Orrie Myers, had initial production of 600 barrels of oil per day and by 1971 had produced 650,000 barrels of oil. Thousands of wells were drilled in the first half of the 1960's in a frenzied oil boom that saw rigs set up in back yards in Cardington. Approximately 38 million barrels of oil and 35 billion cubic feet of gas have been produced from hundreds of small reservoirs in the Morrow County Consolidated field.

Morrow County and surrounding areas lie above a concentration of erosional remnants (buried hills) of Copper Ridge dolomite formed during the subaerial erosion of the Knox Dolomite during the early Ordovician (Knox unconformity). When these dolomite hills were exposed to the atmosphere and rain waters during the Ordovician, they developed solution cavities (known as vugs) in which hydrocarbons later accumulated. A cap of impervious Ordovician rock trapped the hydrocarbons in the Copper Ridge hills. The trick to finding oil in the Morrow County Consolidated field was to locate these deeply buried hills. This exploration was done primarily with reflection seismic techniques.

More recently, the Rose Run sandstone, a blanket sandstone containing interbedded dolomite within the Knox Dolomite, has become a prime target for hydrocarbon exploration in Ohio. The Rose Run is present beneath most of eastern Ohio, but the primary exploration area is along a linear belt stretching from Ross County on the south northeastward to Ashtabula County. This belt, or subcrop, is the area where the Rose Run sandstone was once exposed at the surface when extensive erosion during the Ordovician produced the Knox unconformity. Oil and gas drillers search for buried erosional remnant hills along the subcrop, a trapping mechanism similar to that in the Copper Ridge dolomite in Morrow County.

Gas was first produced from the Rose Run in 1965 in Holmes County in what is now known as the Baltic field, which continues into neighboring Coshocton County. However, the majority of the Rose Run wells in Ohio (84 percent; 1,700 wells) have been drilled since 1985. The overlying Beekmantown dolomite, part of the Knox Dolomite



Principal Cambrian oil and gas fields and productive trends in the Copper Ridge and Rose Run. Modified from Riley and others (1993).

but of probable Ordovician age, also has been a productive hydrocarbon target.

Although the basal Cambrian Mt. Simon Sandstone has not as yet produced oil and gas in economic quantities, it has been an important unit for disposal of liquid industrial waste through Class I injection wells (see *Ohio Geology*, Fall 1992/Winter 1993). Currently, 12 wells at four sites in Ohio inject waste chemicals into the Mt. Simon. This unit is one of the more ideal geologic units in Ohio for disposal and long-term storage of these liquid wastes because it is relatively deep below the surface (2,500 to 10,000 feet), it has comparatively high porosity and permeability, and it is underlain and overlain by impervious confining layers (aquitards) that prevent migration of injected fluids.

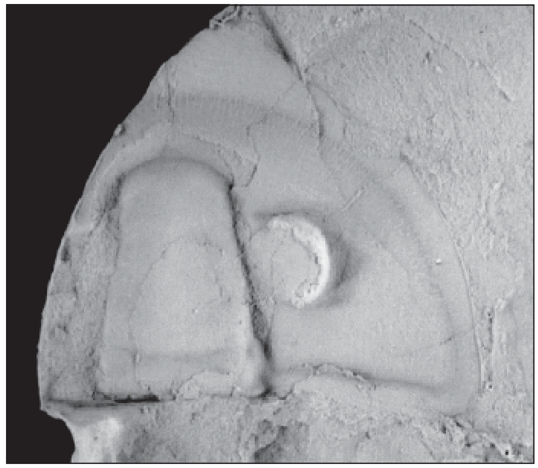
CAMBRIAN LIFE

Although the beginning of the Cambrian marks the first widespread appearance of abundant, multicellular marine organisms capable of fossilization, discoveries since pioneering geologic investigations of the last century have revealed that life teemed in the late Precambrian. But many of these organisms lacked hard parts and were therefore only preserved in special depositional situations. These soft-bodied organisms are collectively known as the Ediacaran fauna, in reference to a Late Precambrian locality in South Australia from which numerous specimens have been described. This fauna is now known from a number of localities worldwide.

But the Ediacaran animals are comparatively simple organisms in comparison to life that literally burst onto the scene early in the Cambrian. A sample of this diversity and abundance was discovered by U.S. Geological Director and Smithsonian Institution Secretary Charles D. Walcott in 1909 in the Burgess Shale, of Middle Cambrian age, on the slope of Wapta Mountain in what is now Yoho National Park, near Field, British Columbia. This remarkable assemblage of now-famous soft-bodied organisms gave the first indications that almost all of the major phyla were present during the Cambrian. In 1984, a discovery of fossils on Maotian Mountain in southwest China indicated that this phyletic diversity was present during the Early Cambrian, only a few million years after the end of the Precambrian. Even fishes swam in the seas by the end of the Cambrian.

Traditionally, the Cambrian is known as the Age of Trilobites because these arthropods constitute perhaps 60 percent of the fossils known from this system and have proved to be wonderful index fossils for comparative dating and correlation of rock units. However, brachiopods, echinoderms, gastropods, graptolites, sponges, and a host of other groups are known from Cambrian rocks. These animals lived in a marine environment. The terrestrial environment, so far as we know, was devoid of animals and probably plants except, perhaps, for algae and lichens.

Although Ohio's Cambrian rocks constitute the least well known Paleozoic system in the state because they are nowhere exposed at the surface, our knowledge of them is increasing rapidly because of intensive exploration and drilling activities for hydrocarbons and their suitability for disposal of liquid industrial wastes. We are beginning to discover that the 65-million-year-long Cambrian Period was an important interval in Ohio's ancient history, not only economically but also because depositional and tectonic events set a foundation for younger, overlying rock systems. We are but at the beginning of discovery of the secrets of Ohio's Cambrian.



Partial cepahlon of a Cambrian trilobite, Cedaria *cf.* C. woosteri, *recovered from the upper part of the Eau Claire Formation from a depth of 2,821 feet in the Survey's Warren County deep core. This specimen and other fragmentary trilobites were associated with remains of inarticulate brachiopods, echinoderms, graptolites, and trace fossils. These are the oldest known macroscopic fossils from Ohio (see* Ohio Geology, *Spring 1992). Magnification 3.5X. Photo by Loren E. Babcock.*

ACKNOWLEDGMENTS

We thank Ron Riley and Mark Baranoski of the Survey and Mike McCormac of the Division of Oil and Gas for assistance with this article.

FURTHER READING

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Sherry Weisgarber receives award

Sherry L. Weisgarber with the Ohio Aggregates Association's Ed Hole Award.

Sherry L. Weisgarber, geologist and mineral statistician in the Division's Industrial Minerals Group, received the Ed Hole Award from the Ohio Aggregates Association at their annual meeting in November 1996. This award for excellence is given annually to an individual not directly employed by the aggregates industry. Sherry received the award in recognition of her outstanding effort in timely compilation of the annual *Report on Ohio mineral industries,* and in coordinating the Division's annual teachers workshops on Ohio's Mineral Industries & the Environment.

Sherry began her career with the Division of Geological Survey in 1984 after receiving bachelor's and master's degrees in geology from Kent State University and serving as an instructor in geophysics at Youngstown State University. Soon after coming to the Survey, Sherry assumed responsibility for compiling the annual *Report on Ohio mineral industries*, which, through her efforts, has become one of the premier state mineral-statistics and producer-directory publications in the country. This publication is highly regarded by Ohio's mineral producers for its completeness, accuracy, and timeliness.

Sherry has been the organizer and coordinator of the annual teachers workshops sponsored by the Division of Geological Survey and the University of Akron since 1985. These workshops give elementary and secondary school teachers a fundamental background in Ohio geology, society's needs for industrial minerals and mineral fuels, and the ways in which mining and environmental concerns can be accommodated.

Sherry has been very active in earth-science education by making frequent classroom presentations on Ohio geology, industrial minerals and mineral fuels, and opportunities for women in science. She compiles the Division's *List of educational resources*, a free 28-page publication that has been of great help to teachers and others seeking earth-science educational information.

Jim McDonald is Division Employee of the Year

Jim McDonald (left) receives the 1996 Employee of the Year Award from Ohio Department of Natural Resources Director Donald C. Anderson (center) and Division Chief Thomas M. Berg (right).

James McDonald, geologist in the Petroleum Geology Group, received the 1996 Employee of the Year award at the Survey's annual Christmas luncheon. This award recognizes surperior efforts and contributions by an employee and has special significance because awardees are selected from nominations submitted by Division staff.

Jim is responsible for developing and maintaining the Division's computerized geologic databases and is one of the Survey's resident computer experts. This expertise has been critical in the Survey's efforts to quickly computerize many aspects of geologic research and mapping, which is recognized and appreciated by the Division staff.

After receiving a bachelor's degree in geology from the University of Delaware and a master's degree in geology from The Ohio State University, Jim began working for the Survey in 1990 as a Natural Resources Specialist intern. In early 1991, he was appointed to a permanent position as a geologist. Jim serves on the National Geologic Map Database Committee and on the Ohio Geographically Referenced Information Program (OGRIP).

Jim's professional interests include petroleum geology, geostatistics, geophysics, computer mapping, and geographic information systems. He is originally from New Jersey and lives in Columbus.

JEAN M. LESHER, 1925-1997

Jean M. Lesher

It is with regret that we report the death of Jean M. Lesher, former typesetting and printing technician for the Division of Geological Survey, on January 7, 1997. Jean retired in 1992 after 30 years of service to the Survey. She was responsible for typesetting and layout of more than 170 Survey publications during her long career. The high quality of these publications was due in large part to Jean's skills and attention to detail. Jean received the Survey Employee of the Year award in 1989.

During her career, Jean used typesetting equipment that evolved from manual typing to computerized electronic typesetting. Even though the computerized equipment came along late in her career, she quickly adapted and became a skilled operator of this complex new technology. Jean did the typesetting for every issue of *Ohio Geology* from 1981 to 1992.

Jean was originally from Frazeysburg, in Muskingum County. She was an avid horsewoman and enjoyed weekend trail rides around Ohio. She also enjoyed family activities; she is survived by her husband, four children, seven grandchildren, and two great-grandchildren.

Jean maintained her ties with her Survey friends after her retirement. She will be missed by her colleagues at the Survey, but we will reflect on her skills and dedication when perusing one of the many publications that she produced in three decades of effort.

Gas Atlas now available

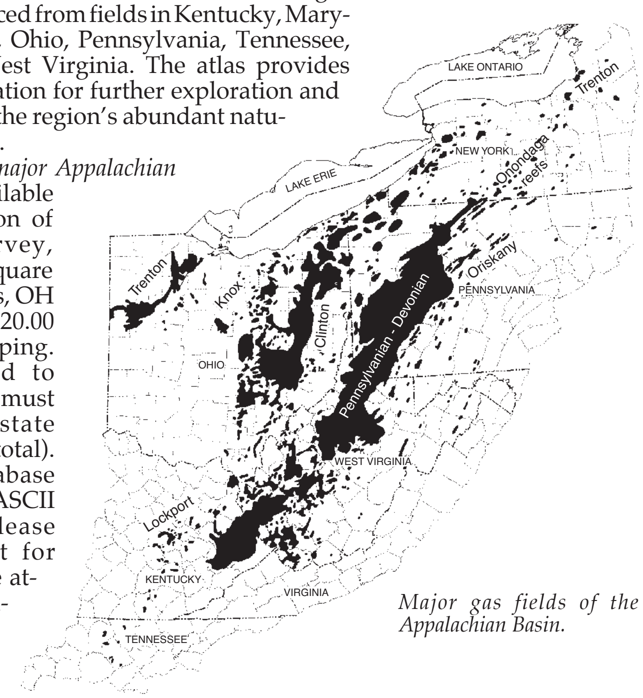
The atlas of major Appalachian gas plays, a 201-page, large-format (17 inches x 22 inches) folio, describes the geology and natural gas production of 30 major gas pools and plays in the Appalachian Basin and contains more than 600 maps, charts, diagrams, and seismic sections. The atlas is the most comprehensive documentation of the geology and production characteristics of natural gas reservoirs in the basin. Also available is an extensive digital database of geologic, reservoir, and production data.

The atlas was published by the West Virginia Geologic and Economic Survey (Publication V-25), edited by John B. Roen (technical editor) of the U.S. Geological Survey and Brian J. Walker (production editor) of the West Virginia Geological and Economic Survey, and prepared by the Appalachian Oil and Natural Gas Research Consortium (AONGRC) for the U.S. Department of Energy, Morgantown Energy Technology Research Center. AONGRC consists of the Kentucky, Ohio, Pennsylvania, and West Virginia Geological Surveys and the Departments of Geology and Geography and Petroleum and Natural Gas Engineering at West Virginia University. Among the 63 contributors of articles in the atlas were Mark T. Baranoski, Glenn E. Larsen, Ronald A. Riley, and Lawrence H. Wickstrom of the Division of Geological Survey and Michael P. McCormac, George O. Mychkovsky, Steven T. Opritza, Thomas E. Tomastik, and Mark E. Wolfe of the Division of Oil and Gas (Mark recently transferred to the Division of Geological Survey).

The atlas project has greatly increased geologic knowledge of natural gas resources in the Appalachian Basin portion of Ohio and surrounding areas. More than 40 trillion cubic feet of gas have been produced from fields in Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The atlas provides essential information for further exploration and development of the region's abundant natural gas resources.

The atlas of major Appalachian gas plays is available from the Division of Geological Survey, 4383 Fountain Square Drive, Columbus, OH 34224-1362 for $20.00 plus $3.00 shipping. Orders shipped to Ohio addresses must include $1.15 state sales tax ($24.15 total). The digital database is available in ASCII or EXCEL (please specify) format for $5.00. If both the atlas and digital database are ordered, cost is $25.00, plus $5.00 shipping, plus $1.44 state sales tax if shipped to an Ohio address ($31.44 total). Credit-card orders may be placed by calling 614-265-6576.

—*Mark T. Baranoski*



Major gas fields of the Appalachian Basin.

The Survey is on line

The Division of Geological Survey now has a site on the World Wide Web to provide geologic information and services to a growing number of Internet users. Web surfers can read this issue of *Ohio Geology* as well as those from the past year. Selected feature articles from previous issues will be added soon.

The site gives information about the Survey, how to contact us, programs and staff, the list of publications, educational resources, Lake Erie programs, energy and mineral resources, and the Survey's core-sample repository.

A link is provided to the Web site of the Ohio Department of Natural Resources and to other state surveys. The Ohio Geological Society also is featured, including a list of their publications.

If you have Internet capability, check us out at *http://www.dnr.state.oh.us/odnr/geo_survey/*. Additions and updates will be added to the site on a regular basis. We welcome comments, suggestions, and questions.

1997 TEACHERS WORKSHOPS

Register now for a week of fun and learning! Join our geologists on visits to mines and quarries. See sand and gravel, limestone, and coal being mined; watch an active oil and gas drill rig , tour a brick plant, and collect lots of rock samples and fossils. At the same time you will learn about the geology of Ohio, why we need mines, quarries, and wells, and how Ohio's miners are protecting the environment. Lots of handouts are distributed! The Ohio's Mineral Industries & the Environment—North teachers workshop is based in Akron and will be held July 7-11, 1997. The Ohio's Mineral Industries & the Environment—South teachers workshop is based in Columbus and will be held July 21-25, 1997. Graduate or undergraduate college credit is required through the University of Akron. For more information and registration materials contact Sherry Weisgarber, ODNR, Division of Geological Survey, 4383 Fountain Square Dr., Columbus, OH 43224-1362 (telephone: 614-265-6588; e-mail: sherry.weisgarber@dnr.state.oh.us), or Dr. Roger Bain, Department of Geology, University of Akron, Akron, OH 44325-4101 (telephone: 330-972-7659; e-mail: rbain@uakron.edu).

HANDS-ON EARTH SCIENCE

by Sherry L. Weisgarber
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DO ROCKS LAST FOREVER?

We think rocks last forever. The boulder we played on in our parents' front yard when we were children is still there for our grandchildren to enjoy. The rock steps to the church are still in use a hundred years later, and the gravestones in the cemetery still mark where our ancestors were laid to rest. These rocks, to us, have lasted forever. But, if you look closely, change is taking place.

This change is called weathering. The term weathering refers to the destructive processes that change the character of rock at or near the Earth's surface. There are two main types of weathering: mechanical and chemical. Processes of mechanical weathering (or physical disintegration) break up rock into smaller pieces but do not change the chemical composition. The most common mechanical weathering processes are frost action and abrasion. The processes of chemical weathering (or rock decomposition) transform rocks and minerals exposed to water and atmospheric gases into new chemical compounds (different rocks and minerals), some of which can be dissolved away. The physical removal of weathered rock by water, ice, or wind is called erosion.

Weathering is a long, slow process, which is why we think rocks last forever. In nature, mechanical and chemical weathering typically occur together. Commonly, fractures in rocks are enlarged slowly by frost action or plant growth (as roots pry into the fractures). This action causes more surface area to be exposed to chemical agents. Chemical weathering works along contacts between mineral grains. Crystals that are tightly bound together become looser as weathering products form at their contacts. Mechanical weathering continues until the rock slowly falls apart into individual grains.

We often think of weathering as destructive and a bad thing because it ruins buildings and statues. However, as rock is destroyed, valuable products are created. The major component of soil is weathered rock. The growth of plants and the production of food is dependent on weathering. Some metallic ores, such as copper and aluminum, are concentrated into economic deposits by weathering. Dissolved products of weathering are carried in solution to the sea, where they nourish marine organisms. And finally, as rocks weather and erode, the sediment eventually becomes rock again—a sedimentary rock.

Two experiments to illustrate the effects of mechanical and chemical weathering are presented below. Two more experiments will be featured in the Spring issue of *Ohio Geology*.

PLASTER AND ICE (MECHANICAL WEATHERING)

What you need: plaster of paris, water, a small balloon, two empty pint milk cartons (bottom halves only), a freezer.

What to do: (1) Fill the balloon with water until it is the size of a ping-pong ball. Tie a knot at the end. (2) Mix water with plaster of paris until the mixture is as thick as yogurt. Pour half of the plaster in one milk carton and the other half in the other. (3) Push the balloon down into the plaster in one carton until it is about 1/4 inch under the surface. Hold the balloon there until the plaster sets enough so that the balloon doesn't rise to the surface. (4) Let the plaster harden for about 1 hour. (5) Put both milk cartons in the freezer overnight. (6) Remove the containers the next day to see what happened.

What to think about: What happened to the plaster that contained the balloon? What happened to the plaster that had no balloon? Why is there a difference? Which carton acted as the control? Why? How does this experiment show what happens when water seeps into a crack in a rock and freezes?

What should have happened: The plaster containing the balloon should have cracked as the water in the balloon froze and expanded. Explain that when water seeps into cracks in rocks and freezes, it can eventually break rocks apart.

A SOUR TRICK (CHEMICAL WEATHERING)

What you need: lemon juice, vinegar, medicine droppers, two pieces each of limestone, calcite, chalk, and quartz.

What to do: (1) Put a few drops of lemon juice on one of each of the four rock samples. (2) Put a few drops of vinegar on each of the other four samples. (3) Look and listen carefully each time you add the lemon juice or the vinegar.

What to think about: What happens when you put lemon juice on each rock? What happens when you put vinegar on each rock? Did the lemon juice and vinegar act the same way on each rock? Why did some of the rocks react differently? What does this experiment have to do with weathering?

What should have happened: Lemon juice and vinegar are both weak acids. The lemon juice contains citric acid and the vinegar contains acetic acid. These mild acids can dissolve rocks that contain calcium carbonate. The lemon juice and vinegar should have bubbled or fizzed on the limestone, calcite, and chalk, which all contain calcium carbonate. There should not have been a reaction on the quartz, which does not contain calcium carbonate. Explain that water commonly contains weak acids that dissolve rocks containing calcium carbonate and other minerals.

SOURCE: *Ranger Rick's Nature Scope: Geology: the Active Earth*, National Wildlife Federation, 1988.

NOTE: Contact Sherry Weisgarber by phone at 614-265-6588 or by e-mail at sherry.weisgarber@dnr.state.oh.us if you are interested in submitting a hands-on activity for this column.

Ohio Geology

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OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF GEOLOGICAL SURVEY

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